DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Environmental Influences on Diel Calling Behavior in Baleen Whales

Mark Baumgartner
Woods Hole Oceanographic Institution
Biology Department, MS #33
266 Woods Hole Road
Woods Hole, MA 02543
phone: (508) 289-2678 fax: (508) 457-2134 email: mbaumgartner@whoi.edu

David M. Fratantoni
Autonomous Systems Laboratory
Physical Oceanography Department
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone: (508) 289-2908 fax: (508) 457-2181 email: dfratantoni@whoi.edu

Award Number: N000141210208
http://www.whoi.edu/sites/mbaumgartner

LONG-TERM GOALS

Baleen whales rely on acoustic communication to maintain contact with conspecifics for the purposes of social interactions, breeding, and possibly coordinated feeding activities. Passive acoustic monitoring takes advantage of this communication to detect whale presence. Unlike odontocetes that use echolocation to forage, calling in baleen whales is by no means obligatory; therefore, the absence of call detections does not always imply an absence of whales. To effectively apply passive acoustic monitoring to research and mitigation problems, we require a much better understanding of the social and environmental factors that influence variability in the calling behavior of baleen whales. One of the most prevalent observations in passive acoustic recordings over scales of days to months is diel calling behavior (i.e., higher calling rates by day versus night or vice versa; Stafford et al. 2005, Wiggins et al. 2005, Baumgartner and Fratantoni 2008). Increased calling activity during particular times of the day is frequently hypothesized to be caused by diel vertical migration of prey, but few studies have directly studied this relationship because it is difficult to continuously observe acoustic behavior and environmental conditions (e.g., prey migration) in areas occupied by whales over time scales of days to weeks.

Our long-term goal is to elucidate the environmental factors that influence baleen whale calling behavior. In particular, we are interested in the impact of prey distribution and behavior on calling rates. While moored acoustic recorders can and have been used to collect persistent observations of whale calling behavior over the requisite time scales, few technologies exist to continuously collect environmental data throughout the water column over these same time scales of days to weeks. Autonomous vehicles, particularly ocean gliders, have the ability to continuously profile the water column on station for durations ranging from days to months while carrying relevant oceanographic and passive acoustic recording instrumentation. Moreover, gliders equipped with instrumentation to

Report Documentation Page					*Form Approved OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **2012**		2. REPORT TYPE **N/A**			3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Environmental Influences on Diel Calling Behavior in Baleen Whales**					5a. CONTRACT NUMBER
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution Biology Department, MS #33 266 Woods Hole Road Woods Hole, MA 02543**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S)
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**					
13. SUPPLEMENTARY NOTES **The original document contains color images.**					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**5**	

monitor whale presence in real time are also capable of surveying for whales and stopping when aggregations are found. We have implemented an automated low-frequency detection and classification system (LFDCS) for baleen whale calls (Baumgartner and Mussoline 2011) on glider-installed DMON instruments to allow known calls (e.g., right whale upcall and gunshot, fin whale 20-Hz pulses, humpback whale downsweeps, sei whale low-frequency downsweeps) to be detected, tallied, and transmitted to a shore-based computer via the Iridium satellite communication system in near real-time. With this capability, gliders can be deployed in areas that are difficult to access with ships (e.g., remote regions or challenging seasons), find whales, and study the environmental factors that influence variability in the whales' calling behavior over time scales of days to weeks.

OBJECTIVES

Our objective is to investigate the relationship between prey behavior and baleen whale calling behavior in a poorly studied environment: the central Gulf of Maine during late fall and early winter. We hypothesize that diel calling patterns are established, in part, by the diel availability of prey: when prey is strongly aggregated during the day at depth, calling activity is reduced while the whales feed. Conversely, during periods of active vertical migration by prey or when prey is diffusely distributed, the whales cannot profitably forage, and therefore increase calling activity and social interactions in lieu of feeding. To address this hypothesis, we will (1) deploy ocean gliders to locate whales and simultaneously observe prey migration behavior and whale acoustic activity, and (2) conduct shipboard zooplankton sampling in the region to identify available prey, including both migrating and non-migrating species.

APPROACH

We will deploy two gliders just west of Jordan Basin in the northern Gulf of Maine for 4-6 weeks from mid-November to mid-December 2012 (Figure 1). Each glider will be equipped with sensors to measure temperature, salinity, chlorophyll fluorescence, optical backscatter, and acoustic backscatter at 1 MHz. Additionally, each glider will be equipped with a DMON/LFDCS to passively record baleen whale calls and to process the acoustic data in real-time to detect, classify, and report whale calls to a shore-based computer system via Iridium satellite communications. When gliders encounter areas of high calling rates as reported by the DMON/LFDCS, a station will be established at that location which will then be occupied by the gliders until whale calls are no longer consistently detected in the area. Based on earlier deployments in this region (Figure 2), we anticipate that whales will remain in a particular area over time scales of many days. While on station, the glider will continuously profile from the surface to just above the sea floor to collect full water column profiles of physical and biological oceanographic properties (e.g., temperature, salinity, chlorophyll fluorescence) as well as a proxy of zooplankton abundance (1-MHz acoustic backscatter). With these data, we will be able to simultaneously characterize species-specific whale calling behavior, diel variability in prey distribution, and temporal variability in oceanographic properties (including changes in background noise and acoustic propagation conditions) to address the hypothesis that diel calling behavior is influenced by temporal variability in environmental conditions (particularly, the diel vertical migration of prey).

We will also conduct a short week-long cruise to the central Gulf of Maine aboard the R/V *Endeavor* to conduct intensive environmental and prey sampling in proximity to the gliders deployed in mid-November. This sampling will (1) allow us to identify both migrating and non-migrating prey in the region so that we can evaluate behaviors in the context of the ecology and life history of each prey

species, and (2) provide in-situ observations of species-specific prey abundance to corroborate the 1-MHz ADCP measurements collected by the gliders. The cruise will occur at the mid-point of the glider mission (Nov 28 – Dec 6, 2012), and all sampling will be focused near the gliders. Since we expect the weather to be rough at that time of year (hence sighting conditions will be poor), we will take full advantage of the glider-borne DMON/LFDCS to locate aggregations of baleen whales for us. To our knowledge, *this will represent the first use of real-time detection and reporting of marine mammal calls from autonomous underwater vehicles to adaptively plan research activities*. Once on scene with whales, we will collect depth-stratified zooplankton samples with a 1-m^2 multiple opening-closing net and environmental sensing system (MOCNESS) capable of catching zooplankton ranging in size from small copepods (e.g., *Oithona* spp.) to large euphausiids (e.g., *Meganyctiphanes norvegica*). Sampling will occur during both day and night to assess diel changes in species-specific vertical distribution. We will also employ a strobe light (BESS, Inc.) on the MOCNESS to reduce net avoidance by large eupahusiids and thereby improve our estimates of euphausiid abundance (after Sameoto et al. 1993). We will also profile with an instrument package consisting of a conductivity-temperature-depth profiler, chlorophyll fluorometer, optical plankton counter (OPC), video plankton recorder (VPR), and a 1-MHz ADCP identical to that carried by the gliders (after Baumgartner and Fratantoni 2008). The net, OPC, and VPR data will be compared to the profiled 1-MHz ADCP data to identify the dominant zooplankton species contributing to the 1-MHz acoustic backscatter. The relationship between acoustic backscatter and species composition and abundance determined during the 1-week cruise will then be used to interpret the ADCP acoustic backscatter observations collected from the gliders over their 4-6 week deployments.

WORK COMPLETED

Final bench testing of the DMON/LFDCS is underway and it will be tested in-situ in the vicinity of whales just to the north of Provincetown, Massachusetts in early October. Glider preparations are underway to be ready for the mid-November 2012 deployments. The cruises aboard the R/V *Endeavor* has been scheduled through the UNOLS system, and I have been in contact with the *Endeavor* staff to plan equipment use and logistics.

RESULTS

Since the fieldwork has not commenced, no scientific results are available at this time.

IMPACT/APPLICATIONS

This project demonstrates a number of capabilities developed over the past several years with ONR support, including (1) the capacity for gliders to persistently study marine mammals in remote or harsh environments in which traditional shipboard studies are impossible, (2) on-board detection, classification, and reporting of low-frequency baleen whale calls from autonomous underwater vehicles in near real-time using the DMON/LFDCS, and (3) the use of these real-time detection reports to direct ships to areas populated with whales. The LFDCS is designed to be extremely flexible such that adding new call types is trivial. In addition to the species listed above, the calls of blue whales, bowhead whales, bearded seals, and ribbon seals have also been included in the LFDCS call library. Although our project focuses on the Gulf of Maine, we anticipate that these capabilities will be extremely useful in other areas for not only ecological research, but for mitigation applications as well.

REFERENCES

Baumgartner, M.F. and S.E. Mussoline. 2011. A generalized baleen whale call detection and classification system. Journal of the Acoustical Society of America 129:2889-2902.

Baumgartner, M.F. and D.M. Fratantoni. 2008. Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. Limnology and Oceanography 53:2197-2209.

Sameoto, D., N. Cochrane and A. Herman. 1993. Convergence of acoustic, optical, and net-catch estimates of euphausiid abundance - use of artificial light to reduce net avoidance. Canadian Journal of Fisheries and Aquatic Sciences 50:334-346.

Stafford, K. M., S. E. Moore, and C. G. Fox. 2005. Diel variation in blue whale calls recorded in the eastern tropical Pacific. Animal Behaviour 69:951–958.

Wiggins, S. M., E. M. Oleson, M. A. Mcdonald, and J. A. Hildebrand. 2005. Blue whale (*Balaenoptera musculus*) diel call patterns offshore of Southern California. Aquatic Mammals 31:161–168.

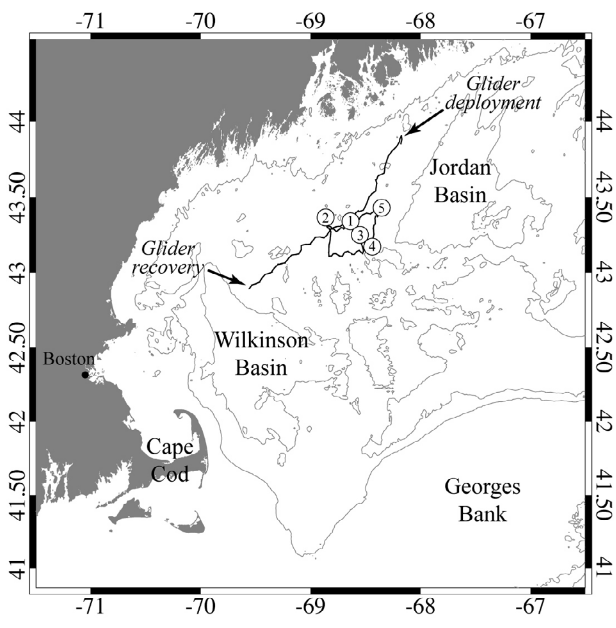

Figure 1. Track of ocean glider deployed in the central Gulf of Maine from mid-November to mid-December, 2009, including stations (circled numbers) at which the glider remained for periods ranging from 1.5-4 days.

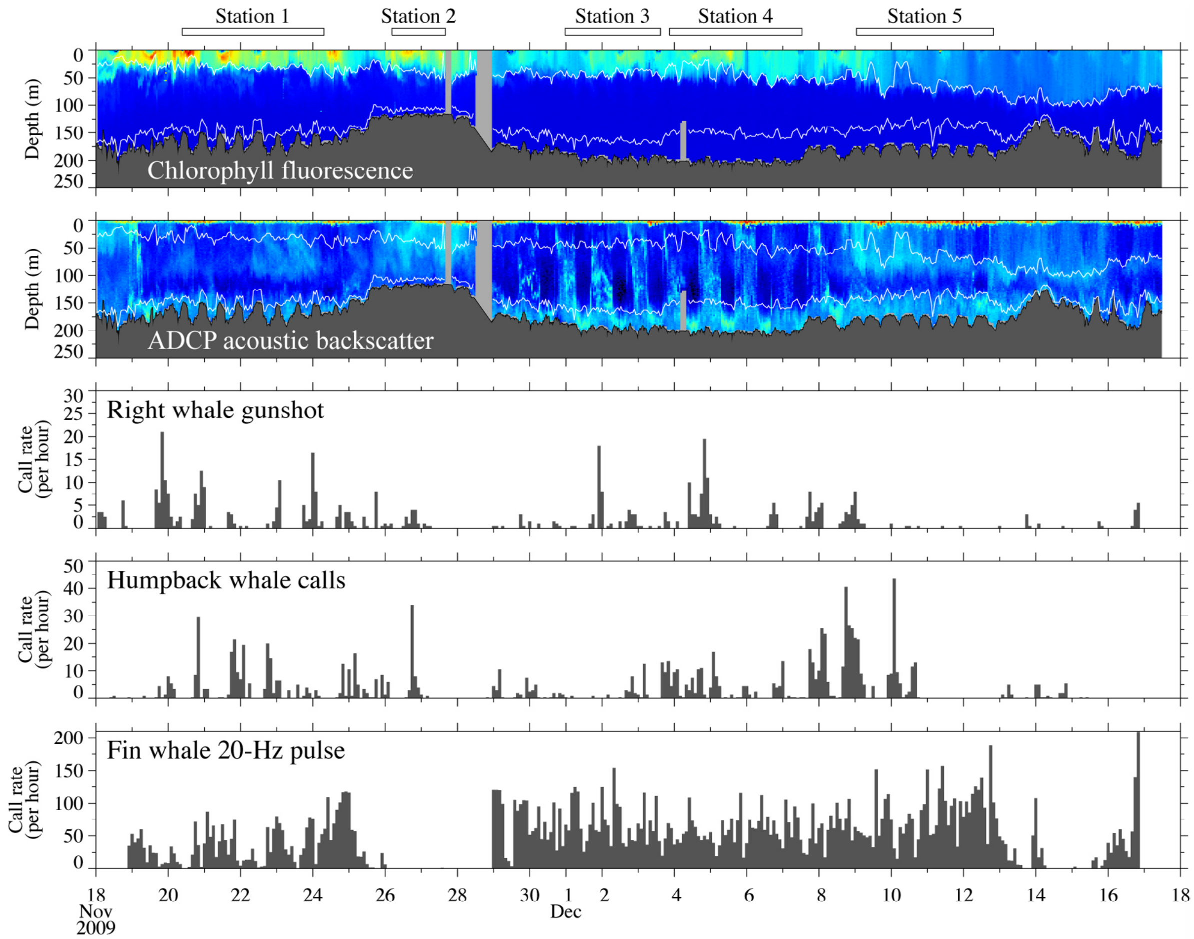

Figure 2. Glider-based observations of chlorophyll fluorescence, acoustic backscatter, and calling rates of right, humpback, and fin whales during 2009 deployment. White lines in top two panels trace the bottom of the surface mixed layer and the top of the bottom mixed layer. Note in acoustic backscatter the diel vertical migration of an unknown organism from November 29 to December 9. Calls detected using the LFDCS of Baumgartner and Mussoline (2011).